Author manuscript, published in "38th Lunar and Planetary Science Conference, (Lunar and Planetary Science XXXVIII), held March 12-16, 2007 in League City, Texas. LPI Contribution No. 1338, p.1679 United States (2007)"

CASSINI VIMS AND ALTIMETER JOINT STUDY OF TITAN SURFACE. S. Rodriguez[1], M. Crapeau[2], S. Le Mouelic[3], Ph. Paillou[2], C. Sotin[3], S. Wall[4], B.J. Buratti[4], R.H. Brown[5], P.D. Nicholson[6], K.H. Baines[4] and the VIMS and RADAR science teams,[1] Laboratoire AIM, Centre d'étude de Saclay, DAPNIA/Sap, Centre de l'Orme des Merisiers, bât. 709, 91191 Gif/Yvette Cedex France, (email: sebastien.rodriguez@cea.fr), [2] Observatoire de Bordeaux, France, [3] Laboratoire de Planétologie et de Géodynamique de Nantes, France, [4] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [5] Lunar and Planetary Lab and Stewart Observatory, University of Arizona, Tucson, USA, [6] Cornell University, Astronomy Department, USA.

Introduction: The joint NASA-ESA-ASI Cassini-Huygens mission reached the saturnian system on July 1st 2004. It started the observations of Saturn's environment including its atmosphere, rings, and satellites (Phoebe, Iapetus and Titan). Titan, one of the primary scientific interests of the mission, is veiled by an ubiquitous thick haze **[1]**. Its surface is unreachable to ultraviolet and visible wavelengths, but can be seen in some infrared atmospheric windows and for greater wavelengths, in the case of an unclouded low atmosphere **[2,3]**.

Onboard the Cassini spacecraft, the VIMS (Visual and Infrared Mapping Spectrometer) instrument has already proved to be able to successfully pierce the veil of the hazy moon and image its surface in the infrared wavelengths, taking hyperspectral images in the range 0.4 to 5.2 µm. Since July 2004, VIMS acquired image cubes with spatial resolution ranging from a few tens of kilometers down to less than one kilometer per pixel, demonstrating its capability for mapping more than 70% of Titan's surface and studying its composition and geology **[4,5,6,7,8,9,10,11]**.

Also in the Cassini orbiter payload is the Ku-band RADAR experiment that can operate in altimeter mode. Exclusively dedicated to Titan's observations, this second active mode has been designed primarily to retrieve Titan's surface elevation and study its topography.

We present here the comparative analysis of the altimeter track recorded during the first Titan flyby (26 October 2004, tagged TA) and VIMS images over the same regions acquired during the 13th flyby (30 April 2006). In particular, we present here the first non-topographic analysis of Cassini altimeter data along with a tentative correlation with VIMS observations.

TA Cassini altimeter track: During the TA Titan flyby (26 October 2004), Cassini RADAR recorded its first altimeter track, beginning just after the end of the the SAR swath acquisition **[12]** (see **figure 1**). The linear part of TA altimeter track runs from -10°E to -2°E in longitudes and from 28° to 23.5° in latitudes (see **figure 1**). Looking at the leading edge position of the returned altimeter pulse echo gives direct estimation of the relative elevation of Titan's surface (**figure 2a**) with a spatial resolution to the order of the radar beam size at Titan's surface (a few tens of kilometers) and a theoretical vertical precision less than 100m. Calculations show very smooth reliefs along the track with at best 200 meters elevation differences over 400 km (**figure 2a**).

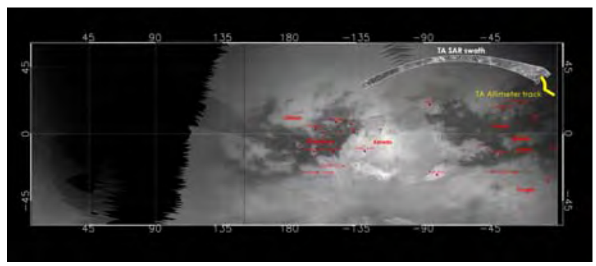

Figure 1. TA SAR swath and altimeter track overlying a global view of Titan's surface imaged by VIMS.

Along with elevation restitution, Cassini altimetry data can also be used to retrieve the radar reflectivity of Titan's surface, as it is done on the Earth in icy contexts like in the Antarctic. The radar reflectivity σ_0 corresponds to the total energy echoed that depends essentially on Titan's surface roughness and composition. The computed σ_0 presents a clear signal parabolic decrease over 100 km strongly correlated with the smooth surface depression inferred from topography estimation, witnessing a change in surface nature at this location (between 27° and 25.5° in latitudes - see **figures 2a and 2b**). It might be due to the local presence of a more microwaves absorbing material. This parabolic decrease also presents a narrow central peak which can be interpreted by a slight and very localized variation of the surface properties.

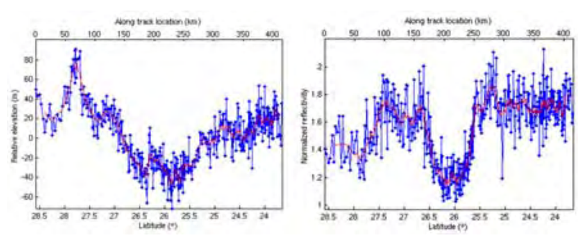

Figure 2. *Left (a):* Surface elevation calculations from TA altimeter data. *Right (b):* Radar reflectivity derived from TA altimeter data.

Joint analysis of RADAR TA altimeter track and the T13 VIMS images: The 30th April 2006 (T13 Titan flyby), the VIMS instrument acquired hyperspectral images over the TA altimeter track. 2.03 µm I/F and corresponding 2.03/1.27 µm bands ratio mosaics of Titan's terrains observed during this flyby are shown in **figure 3 (inset a)** and **3 (inset b)**. The TA altimeter track is symbolized by a red line. The 2.03/1.27 µm bands ratio map is corrected from atmospheric aerosols contribution, following the method developed by **[9]**, providing a good indicator for the surface relative water content where the ratio is particularly low. A dark linear structure visible in VIMS data (2.03 µm images and 2.03/1.27 µm ratio) crosses the altimeter ground-track.

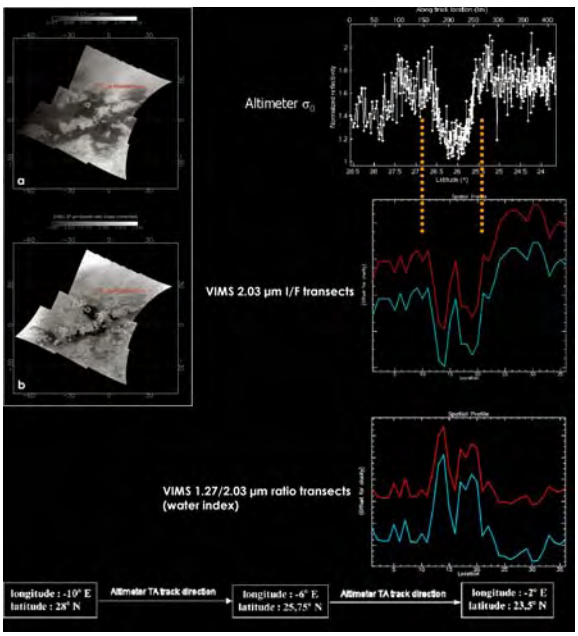

Figure 3. Cross comparison between TA altimeter reflectivity (*top right*) and infrared VIMS transects over the altimeter track (2.03 µm transects at *middle right* and 1.27/2.03 ratio transects at *bottom right*). Are indicated at the bottom the longitudes and latitudes along the VIMS transects. *Inset a:* 2.03 µm albedo mosaic of Titan's terrains observed during T13 flyby. *Inset b:* 2.03/1.27 µm bands ratio map corrected from atmospheric aerosols contribution, following the method developed by **[9]**, over the same regions. The TA Altimeter track is symbolized by the red line. A dark linear structure visible in VIMS data crosses the track.

We extract the VIMS I/F transect exactly over the TA altimeter track. The cross comparison between Cassini VIMS and RADAR altimeter observations, presented in **figure 3**, allows us to investigate the compositional and physical characteristics of the terrains located along the altimeter track, in particular the low topographic and reflectivity feature seen in **figures 2a and 2b**. The radar reflectivity shows a particularly strong correlation with 2.03 µm I/F level along the track (signal decrease and "right/left" imbalance - see **figure 3 top right**). The infrared data also present a "central peak" exactly at the same location than the radar data do. On its side the 1.27/2.03 µm ratio transect shows a clear anti-correlation, arguing for a local water ice enrichment strongly linked with the negative topography and the decrease in radar reflectivity. We are possibly in presence of a structure, maybe an ancient channel of liquid methane, where Titan's icy bedrock is exposed.

Conclusions and perspectives: Our first study shows clear contrasts of the radar reflectivity along the altimeter track acquired during the first Titan flyby (TA). This distinct decrease in radar reflectivity is somewhat correlated with a slight surface height variation. The 13th Titan flyby (T13) provided us VIMS medium resolution observations of the same region. Infrared I/F transect along the TA altimeter track presents a very strong correlation with the radar reflectivity. These correlations between infrared I/F and radar reflectivity variations certainly indicate a change in the surface nature and the presence of a clearly defined surface structure under the track. VIMS 2.03/1.27 µm channels ratio transect along the altimeter track also suggests a local enrichment in water ice associated with a smooth depression, maybe witnessing ancient channels.

Future Titan flybys will allow more VIMS/altimeter cross comparisons. Separately, the radar and infrared data are difficult to interpret, but together they are a powerful combination. These studies will provide complementary information about the nature and structure of Titan surface, as well as the VIMS/SAR cross studies **[13,14]**. Moreover, this study is an original use of the CASSINI altimeter.

References: **[1]** Brown R.H. et al. (2003), *Icarus, 164, 461*. **[2]** Smith P. H. et al. (1996) *Icarus, 119, 336*. **[3]** Rodriguez S. et al. (2003), *Icarus, 164, 213*. **[4]** Sotin C. et al. (2005), *Nature, 435, Issue 7043, 786*. **[5]** Jaumann R. et al. (2006), *P&SS, 54, Issue 12, 1146*. **[6]** Buratti B.J. et al. (2006), *P&SS, 54, Issue 15, 1498*. **[7]** Mc Cord T.B. et al. (2006), *P&SS, 54, Issue 15, 1524*. **[8]** Nelson R.M. et al. (2006), *P&SS, 54, Issue 15, 1540*. **[9]** Rodriguez S. et al. (2006), *P&SS, 54, Issue 15, 1510*. **[10]** Barnes J.W. et al. (2006), *GeoRL, 33, Issue 16, CiteID L16204*. **[11]** Barnes J.W. et al. (2007), *Icarus, 186, Issue 1, 242*. **[12]** Elachi C. et al., *Science, 308, Issue 5724, 970*. **[13]** Barnes J.W. et al., *LPSC abstract, this issue*. **[14]** Soderblom L. et al., *P&SS, submitted*.